STUDY OF THE DECAY AND RECOVERY OF ORBITING ARTIFICIAL SPACE OBJECTS

Semiannual Progress Report No. 10
for the period 1 November 1968 through 30 April 1969

Grant No. NGR 09-015-007

Principal Investigator
Albert Werner

May 1969

Prepared for

National Aeronautics and Space Administration
Washington, D.C.

Smithsonian Institution
Astrophysical Observatory
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In accordance with the requirements of the grant document and as further detailed in NASA letter SC-NsG-563 dated 13 April 1964, the following report of activities for the period 1 November 1968 through 30 April 1969 is submitted. The 6-month period reported conforms with the first 6-month period of the current grant year.

Predictions of decays continue to be received by Moonwatch from NORAD early enough for stations throughout the observing network to be alerted in time for possible observation.

The status of the Volunteer Flight Officer's Network (VFON) relationship with Moonwatch has been changed. As of 1 January 1969, the VFON has been removed from being sponsored by United Airlines to be wholly administered by the Moonwatch Division of Smithsonian Astrophysical Observatory, operating under a contract with the United States Air Force.

A photographic sighting of a predicted decay was reported by the Smithsonian astrophysical observing station at Maui, Hawaii. Predicted decay observations have been reported by ground-based Moonwatch observers as well as by members of the VFON.

1. PREDICTIONS

Predictions of decays continue to be received regularly from the Space Defense Center. Corrected orbital information has been received near enough to the time of decay for predictions to be calculated for selected stations having possible visibility. Satellite-decay information is also relayed through the Space Defense Center to the VFON airline pilots while in flight, so that they can be alerted to the possibility of observing a reentering satellite.

In the period 1 November 1968 through 30 April 1969, 159 satellites decayed. Of this total, NORAD telegraphed special tracking and impact predictions covering the reentries of 61 primary satellite objects for which Moonwatch calculated decay predictions for all stations with possible visibility (see Appendix A).

2. GEOGRAPHICAL COVERAGE

Moonwatch now has a total of 140 teams. The number of countries represented remains at 25.

The VFON covers 2.6 million unduplicated air miles of the earth and has the cooperative participation of 118 airlines located in 54 countries.

3. COMMUNICATIONS

The general communications situation continues to show improvement. Expansion of telegraphic cooperation with the Radio and Space Research Station (RSRS) at Slough has resulted in a system for relaying, directly to SAO, British observations of satellites about to decay. Similar cooperative arrangements were also made for our Moonwatch observers in Australia, New Zealand, and Japan through existing telecommunication networks.

4. OBSERVATIONS

Observations of the predicted decays of the following objects were reported by observers:

68-102B	Cosmos #253 Rocket Body	on 20 November	1757 UT
68-109B	Heos A Rocket Body	on 27 December	1506 UT
68-118A	Apollo 8 Command Module	on 27 December	1540 UT
68-107B	Cosmos #257 Rocket Body	on 16 January	0222 UT

The observations are described in the extracts (see Appendix B).

Numerous other observation reports received from the VFON were of unpredicted satellite decays as well as of short-lived satellite objects, fireballs, and other atmospheric entry events.

5. GENERAL

Echo 2, because of its great size, construction, and special interest, is being given particular attention during the last several weeks of its life — as was done for Echo 1.

Procedures for receiving observation reports, as outlined in Section 3, are proving to be most effective. Moonwatch stations in Britain, Australia, New Zealand, and Japan are now included for early reporting procedures, along with Moonwatch stations within the United States and Europe. The early arrival of Echo 2 observations through the use of special reporting procedures permits time and position corrections to be applied in the Differential Orbit Improvement Program (DOI) so that an updated and workable orbit can be achieved.

Steps have been initiated for forming a network within the Moonwatch observer network for the purpose of observing artificial satellites at great distances from the earth.

Special computer programs are being designed and evaluated for this purpose. Selected observing sites are also being identified and developed

for this purpose. We expect that the observational capability of this network will enhance the possibility of observing this class of satellites, either while in orbit or near reentry.

Furthermore, observing methods developed for this system will also apply to the observing of Apollo mission events that occur at great distances from the earth.

APPENDIX A

Predictions

	NORAD			ACTUAL	
Satellite	Pred.on	Prediction	±	Time	±
68-48A	N 2/1739	N 2/1751	0030	N 2/1724	0010
68-56A	2/1912	2/2047	0030	2/2122	0010
68-96B	2/2335	3/0043	0200	2/2237	0015
68-85C	4/1419	4/1846	0100	4/1752	0008
68-59A	6/0406	6/0923	0100	6/1058	0010
68-28A	10/0227	10/0520	0100	10/0521	0010
68-101B	12/0036	12/0903	0040	12/0700	0005
68-79A	12/2329	13/0719	0045	13/0707	0005
68-101E	13/1955	13/2150	0020	13/2053	0010
68-101C	13/2139	13/2355	0030	13/2305	0005
68-83B	16/0420	16/0632	0130	16/0605	0005
68-96A	18/0930	18/1232	0100	18/1123	0010
68-102B	20/0803	20/1934	0200	20/1828	0015
68-96A	23/0250	26/1929	2400	23/2124	0005
68-104B	27/1319	27/1643	0100	27/1559	0005
68-105B	D 4/2144	D 5/0212	0040	D 5/0132	0003
65-55A	18/0143	18/0439	0020	18/0440	0010
68-109B	27/1019	27/1248	0130	27/1506	0005
68-61B	J 1/0232	J 1/0757	0100	J 1/0734	0003
69-01B	6/1413	6/2054	0200	6/1949	0015
69-01C	6/2337	7/0619	0130	7/0534	0015
68-117B	7/0828	7/1143	0100	7/1134	0003
68-03A	9/0845	9/1244	0100	9/1159	0010
69-02B	11/0504	11/0848	0030	11/0820	0010
69-02C	13/0358	13/0734	0100	13/0729	0008
67-104A	14/1230	14/1808	0115	14/1704	0015
68-83A	15/1916	16/0007	0130	15/2352	0015
68-107B	15/0615	16/0526	0300	16/0222	0024
69-05B	17/0117	17/0926	0130	17/0902	0008
69-03B	16/0700	18/0130	0500	18/0005	0010
68-115C	17/2142	18/0235	0100	18/0228	0010
68-103B	25/0319	25/0516	0010	25/0516	0008
68-08B	30/1719	30/2252	0045	30/2211	0009
68-115B	F 6/1101	F 6/1440	0045	F 6/1430	0008
68-61A	6/1747	7/0038	0100	7/0007	0005
67-95D	8/1850	10/2352	0600	10/2147	0035
68-117A	12/0319	12/0804	0030	12/0755	0005
69-08C	12/1850	13/2056	0300	13/2057	0004
64-11A	18/1952	19/0152	0045	19/0121	0010
68-38B	24/0506	24/0710	0045	24/0906	0015
69-10A	24/0534	24/2253	0500	24/1842	0020
69-15B	M 4/1134	M 4/1858	0100	M 4/1813	0002
67-95A	4/1856	4/2255	0045	4/2320	0010
68-107A	4/2240	5/0412	0100	5/0345	0020
69-17B	5/0813	5/1136	0100	5/1111	0015
67-120A	8/2301	9/0429	0100	9/0424	0018
69-22Y	12/0720	12/1133	0200	12/1043	0016
69-12B	17/1426	17/1939	0030	17/1855	0006
69-23B	20/2048	22/0248	0300	22/0207	0010
69-18D	22/0219	22/0415	0200	22/0354	0003

	NORAD			ACTUAL	
Satellite	Pred.on	Prediciton	±	Time	±
69-25D	24/0908	24/1448	0200	24/1310	0021
67-104B	28/1614	28/2120	0035	28/1956	0003
69-27B	28/1744	28/2225	0030	28/2146	0028
66-118A	A 5/0853	A 5/1332	0130	A 5/1225	0005
69-43B	13/0056	13/1434	0200	13/1405	0002
69-32B	14/0509	14/0847	0040	14/1204	0009
69-34B	16/0113	16/0353	0100	16/0325	0001
69-38B	17/2242	18/0415	0045	18/0244	0008
69-40B	25/1516	26/1938	0100	26/1916	0010
68-119B	30/0325	30/0710	0100	30/0640	0006

APPENDIX B

Extracts

Moonwatch Newsletter

January 1969

DECAY OF 68-109B

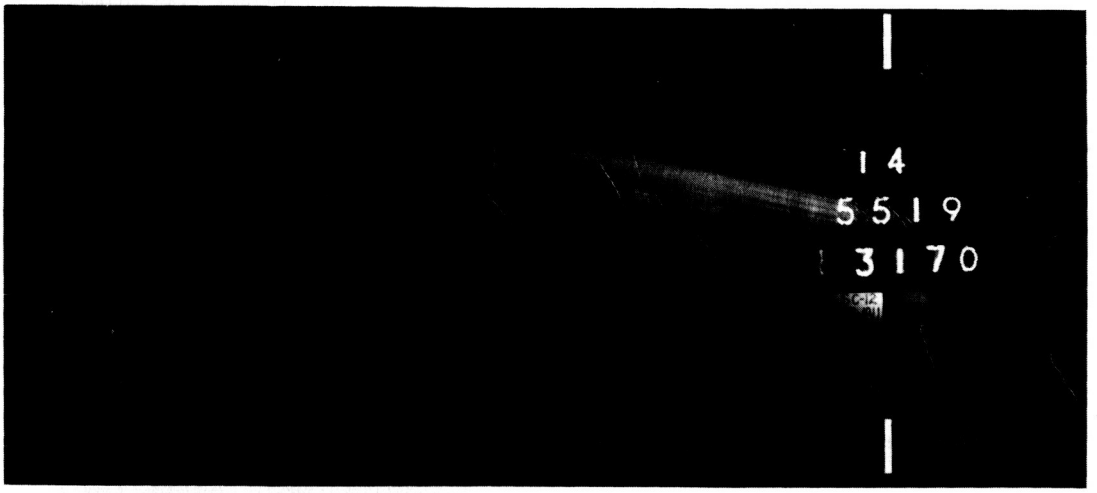
The predicted decay of 68-109B (Heos A rocket body) was observed and photographed by the Smithsonian Astrophysical Observing Station atop Mt. Haleakala on the Island of Maui, Hawaii. Its re-entry was described as follows:

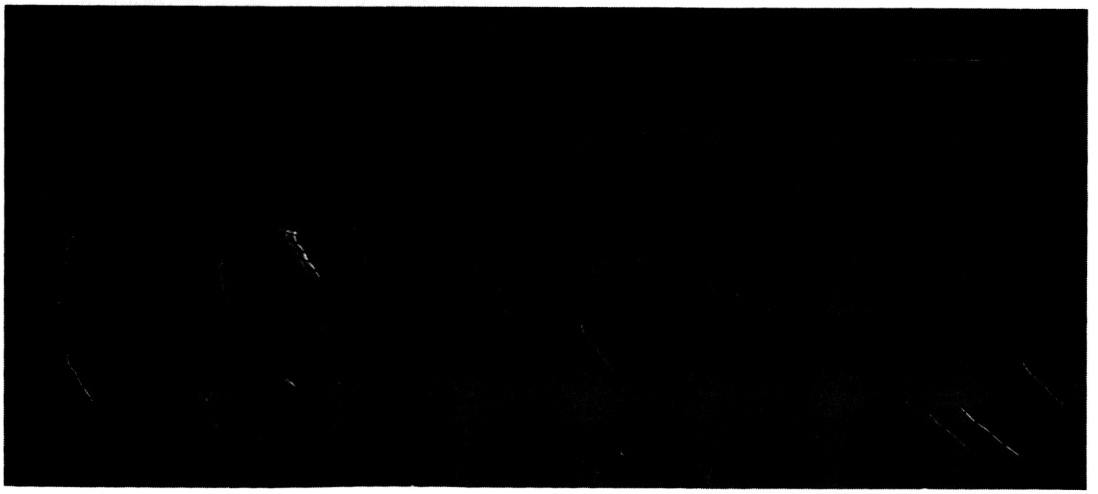
Decay seen Dec 19/1454Z. About 7 meteor-like objects seen trailing "sparks" moving at about 15 to 20 thousand seconds of arc per second of time, from NW to SE as predicted. Lead object was -1 mag., three pieces of +1 mag and numerous pieces that were +4 mag. There were also 100-150 additional pieces clustered within the moving area of a 4-5 degree circle.

Photo 1 Brighter pieces along with small debris. Earliest photo in time sequence. Images are broken by rotating shutter of camera during exposure.

Photos 2 & 3 Horizontal images are stars. All others (more or less verticle) are bits and pieces of decay and show how they are affected by various forces as they penetrate deeper into more dense atmosphere.


14
5459
2429


14
5519
3170



Moonwatch Newsletter

December 1968

RE-ENTRY 68-102B (COSMOS 253 ROCKET)

The predicted decay of Cosmos 253 rocket body was observed and reported by several pilots of the Volunteer Flight Officer's Network. Unfortunately, the Moonwatch stations that might have had visibility were completely clouded out.

Mrs. Doreen Walker (an associate of Desmond King-Hele) was alerted to the possibility of observing the re-entry and fortunately happened to be at a spot where favorable weather conditions permitted her to see what was certainly a spectacular event. Though Mrs. Walker is not a satellite observer, you will agree that her eyewitness account and accompanying sketches are excellent.

Mrs. Walker's Eyewitness Report from Ottershaw, England

"The following sighting was made from my garden in Ottershaw (Lat. 51° 21' N, Long 0° 33' W). I started watching for 1968-102B at about 6.45 p.m. BST (17.54 UT) on 20 November 1968. I was looking in a northwesterly direction, as the rocket was predicted to pass overhead in a direction from NW to SE. At 6.57 p.m. I saw a bright area of light appear in the NNW at an elevation of about 20°. The bright area of light was followed by lines of light which seemed to come from the sides of the bright area. Occasionally brighter balls of light were appearing, as if thrown off from the rocket (Fig. 1). As the rocket moved on across the sky in a SE direction, it reached a maximum elevation of about 40° in the NE and disappeared into a bank of cloud at about 25° elevation in an E direction.

By the time the rocket had reached maximum elevation it appeared as a bright light followed by what appeared to be a cylindrical shape, presumably the cloud of dense debris following the rocket. This cloud of dense debris appeared to be about 3° in length and was followed by a tail of light which was about 10° long (Fig. 2). This tail consisted of bright lines of light from the sides of "cylinder", rather like vapour trails from aircraft; the bright balls of light were still being thrown off the rocket. As these burnt up, each had a shower of sparks behind it. Just before the rocket passed out of sight behind a bank of cloud, the "cylinder" seemed to have bright patches of light at intervals along its edge (Fig. 3). The balls of light which were being thrown from the rocket appeared about every 10 seconds or so. They were brighter than Venus and about 5 to 10 were visible at any one time. Occasionally red and green flashes of light were seen."

The eleven pilots and flight officers of VFON reporting the event were all in close agreement as to the details of re-entry.

Our thanks to you all for an excellent job of reporting.

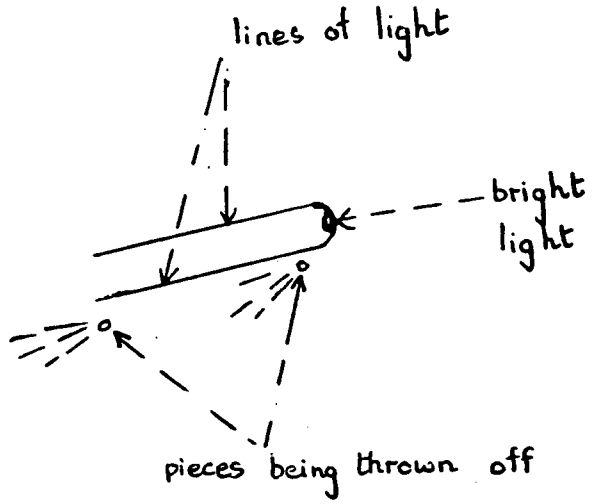


FIG. 1 1968 - 102B as first seen

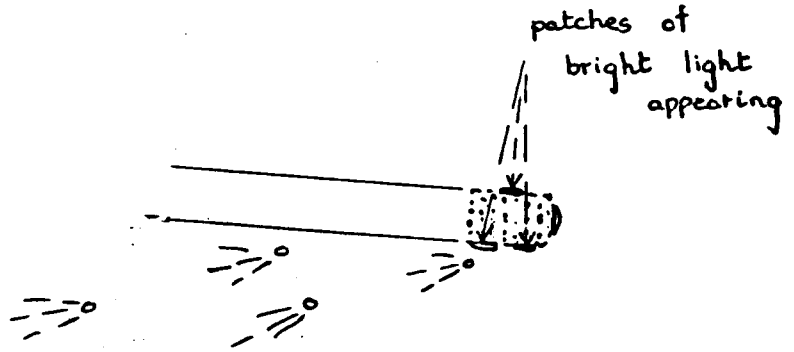


FIG. 3 As last seen

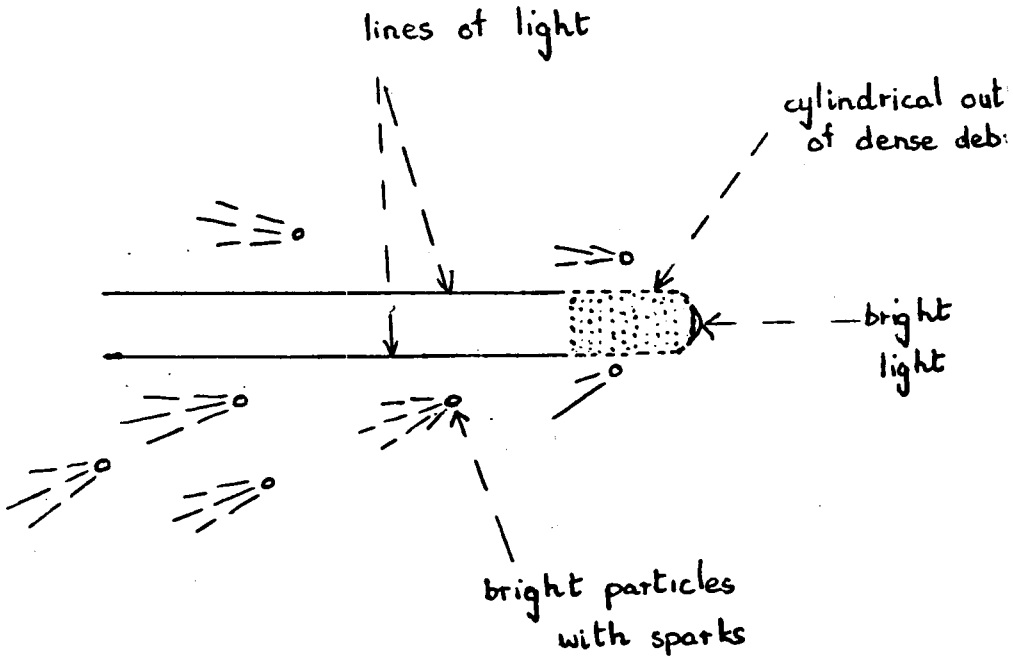


FIG. 2 At maximum elevation

3 STAGES OF RE-ENTRY SKETCHED BY MRS. DOREEN WALKER

Descriptions of the predicted reentry of the Apollo 8 command module follow. They were made by Capt. M. M. Marcum and S/O Gregor J. Schwinghammer, members of the Volunteer Flight Officers Network and employed by Pan American World Airways.

Capt. Marcum's Report:

Having been alerted to the possibility of sighting the re-entry my crew and I were aware of the general area and direction in which to look for the first appearance of the moon-flight. We did not know just how and in what shape it would appear from our point of vantage some 120 miles west of the predicted splashdown point. (The splashdown point was directly on the Honolulu-Sydney track and all aircraft had been re-routed about two degrees of longitude to the west.)

It was a very dark night, the moon having set more than three hours earlier. Flying at 31000 we were having to keep close watch on the radar to avoid the scattered Cumulonimbus and towering cumulus in the area. To the extent practicable, the cockpit was kept darkened so that we could accustom our eyes to searching the western horizon in the area of the constellation Pisces as the time for the re-entry approached. With splashdown calculated at 0551 LZT (1551 GMT) we began our vigil at 0515 LZT. The star Capella, an old navigational friend, was the brightest celestial body in the western sky and we familiarized ourselves with the other stars then in view so that the appearance of the Apollo 8 would be readily apparent. At 0540 LZT we were rather startled to see two relatively large red objects appear on the horizon at our 2:30 position. The two red objects appeared to be quite close with one approximately five degrees higher in altitude than the other. Within seconds, the higher in elevation appeared to separate from the other and began moving rapidly across the sky leaving a long incandescent trail behind it. There was no mistaking the fact that it was the Apollo 8.

Passengers were alerted and I called our company operations office in Honolulu. Here is a verbatim transcript of my description of the re-entry as recorded by the ground station in Honolulu.

"We have the Apollo 8 in sight. He's making a red ball of fire followed by a long streamer of white incandescent material. He's passing now at our one o'clock position and will pass directly in front of us to the impact area right on schedule. The weather in the impact area appears to be very nice. There is an area of cumulus buildup just 50 miles to our left. A really beutiful sight to see - this re-entry with a streamer that must be almost a hundred miles in length.

Capt. Marcum's Report Continued

It's very beautiful and should be visible to people within five hundred miles and perhaps a thousand miles from this point. Directly overhead right now and trailing incandescence which I would estimate to five miles in width and at least seventy-five to a hundred miles in length--and has now passed off to our left to the east. The Apollo 8 is now re-entering and the incandescent trail and fireball have disappeared-- he's now in the atmosphere". End of transcript at 0543 LZT.

While I feel these words spoken while watching the event are most important for your purposes, there are certain facets which I did not report at the time in which you might have some interest. For instance, what happened to the second "object" seen at the same time as the first sighting of the spacecraft? We were so engrossed in watching the re-entry that we forget about it until after Apollo 8 had disappeared from our view. When we again looked for it, it was not visible. While it is conjecture, I feel that it is a distinct possibility that this object was the "life support unit" jettisoned by the Apollo 8 crew just before the re-entry maneuver began.

From it's initial sighting until it's disappearance, the spacecraft covered the distance from horizon to horizon in about three minutes. When first sighted, it could have been described as a cherry red ball of fire. As it continued across the sky and was viewed at a higher apparent altitude, the color appeared to change to yellow tinged with red. Small streaks of light aft of the spacecraft from time to time appered to be from some material being shed by or from the spacecraft.

From the abruptness with which the Apollo 8 disappeared from our view, I would guess that we viewed it right up to the point of drogue chute deployment.

S/O Schwinghammer's Report:

We were very fortunate in being able to observe the arrival of the first manned flight around the moon. We had climbed to 37,000 ft hoping to get the best possible view.

The ship entered as a "red star" at 1539Z. From our relative position, it appeared to be coming directly toward us. It held me in awe since it had that strange appearance of an invading space ship that one might see in a science fiction movie. As the space ship descended into the atmosphere, a long white tail began to form. The capsule, now crossing our left wing, seemed to be climbing (because of our relative position to it) and for a few seconds, I was sure it was bouncing back into space. As the ship passed toward the rear, we could see the comet like tail streak out behind it 100 to 150 miles long. We were close enough so that I could actually distinguish ribbon-like bands

perpendicular to the direction of the tail, and dividing the tail in about three parts. I assume that they were caused by either pressure changes in the atmosphere or changes in power, if power was still used in slowing down. I was the only one of the crew to notice the ribbons.

The sight of the long tail with the fireball (now white) at its forward tip was spectacular.

As the space ship dropped further into the air mass, and slowed its velocity the tail began to shorten and finally disappear, while the fiery capsule gradually changed to a red glow.

From the National Geographic

May 1969

PAINTING BY WILLIAM H. BOND, GEOGRAPHIC ART DIVISION © N.G.S.

Passengers on a jetliner view Apollo 8's re-entry

"IN MY 26 YEARS of airline flying, this is the most spectacular, sensational thing I've ever watched," says Capt. James Holliday of the scene portrayed above. Skipper of Pan American flight 812 from Fiji to Honolulu on December 27, Captain Holliday was piloting his Boeing 707 across the Pacific at the moment of Apollo 8's re-entry. Suddenly he spotted a tiny pinpoint of light a bit below and left of the star Capella. Immediately he announced the sighting over the public address system, and passengers and crew could see the spaceship over the left wing tip.

"We watched as the color of the capsule brightened to pinkish red," said Holliday, "and we noticed a tail similar to that of a comet forming directly behind. The tail was short at first, a dull orange streak. As Apollo 8 gradually came closer in the star-filled black sky, its glow changed from soft orange to yellow and, finally, to incandescent white. The orange-red tail grew longer and more vivid. It did not flare; it was perfectly straight and of constant thickness, like a slash made by an artist on a piece of black velvet. We estimated the length of the tail at 125 miles.

"We watched the spacecraft for three minutes. By that time I had turned the plane around a full 180 degrees to follow it. When it neared the splashdown area, the tail grew shorter and the brilliant white light diminished in intensity. Suddenly it went out, as if somebody had snuffed a candle—the Paul Bunyan of all Roman candles. We never saw the three leading characters of this drama. There was no musical score, nor was one needed. But the set was fantastic—and we had the best seats in the house!"